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COTTONTAIL SPECIES IDENTIFICATION: ZOOARCHAEOLOGICAL USE OF MANDIBULAR MEASUREMENTS

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ABSTRACT.–It has been suggested that archaeologically recovered cottontail mandibles may be identified to species by examining the relationship between mandibular depth and alveolar length even though most of the cottontail skeleton is not diagnostic to species. Study of cottontail mandibles recovered by the Dolores Archaeological Program from Anasazi sites in southwestern Colorado has supported this suggestion but indicated that reliable species identification requires a more thorough analysis of traits. Further investigations should be directed to the topic of subspecific variation as well.

INTRODUCTION

Although the skeletal remains of cottontail rabbits commonly are recovered from archaeological sites (e.g. Bertram and Draper 1983, Binford et al. 1983, Cordell 1977), osteological separation of these cottontail species seldom is possible. Findley et al. (1975:83-86) have noted that the taxonomic relationships between the eastern cottontail *(Sylvilagus floridanus)*, the mountain or Nuttall's cottontail *(Sylvilagus nuttallii)*, and the desert cottontail *(Sylvilagus audubonii)* require further clarification, at least in New Mexico. Nevertheless, these authors have suggested that mandibular and dental characters can be used to separate the desert cottontail from the other two species even in archaeological and fossil materials. These characters, particularly mandibular measurements, have been used in several zooarchaeological analyses of cottontail remains to determine the species represented (Akins 1984; Anderson 1980; Harris 1963, 1970; Pippin 1979). This article indicates that the identification of cottontails is not necessarily as straightforward a matter as suggested by Findley and his coworkers.

The bones of cottontail rabbits occur more frequently in sites excavated by the Dolores Archaeological Program[1] than those of any other single taxon (Neusius 1985). For this reason alone it was considered desirable to determine the cottontail species represented. However, because there was reason to expect both desert and Nuttall's cottontail[2] to be present and because the habitat preferences of these species were known to differ (Armstrong 1972:82, 85; Bissell and Dillon 1982:7), further study of the Dolores cottontail remains promised to provide insights into Anasazi exploitation strategies (Flint and Neusius in press). Thus, we used the characters suggested by Findley and his coworkers to assign cottontail mandibles recovered at Dolores to species. We found the use of bivariate plots less than satisfactory because the accuracy of species identification is not evident. While the use of discriminant analysis was more satisfactory for our purposes, this approach suggested that the proper identification of cottontail mandibles is a more complex task than anticipated and deserving of further study.

SPECIES DETERMINATIONS USING BIVARIATE PLOTS

According to Findley et al. (1975:84-85) the desert cottontail has a deeper jaw and a shorter toothrow than either the Nuttall's or the eastern cottontail. The characters used

to measure this are the alveolar length and the depth of the lower jaw (Fig. 1). Alveolar length is defined as the distance between the anterior margin of the third premolar and the posterior margin of the third molar. However, these authors suggest that the distance between the anterior border of P_3 and the posterior margin of M_1 will suffice in studies of archaeological and fossil material. Mandibular depth is defined as the distance between the anterior border of the fourth premolar and the ventral border of the mandible at right angles to the toothrow.

Dental characteristics also may be useful in identifying cottontail species according to Findley and his coworkers. The borders of the desert cottontail's posterior external reentrant angle on premolar 3 are strongly crenulated, while those of the eastern cottontail are less crenulated and those of Nuttall's cottontail are smooth (Findley et al. 1975: 85-86).[3]

In the Dolores study osteological measurements were made on 302 cottontail mandibles from 27 archaeological sites located in the Dolores project area. Nineteen of these apparently were from juvenile individuals, and these were omitted in the subsequent analysis.

The measurements taken followed those recommended by Findley and his coworkers. As shown in Figure 1, distance A is the depth of the jaw, measured with a vernier calipers. In order to standardize this measurement, the mandible was placed on graph paper with the cheektooth row aligned vertically and the labial side up. The stationary part of the calipers then was placed on the most anterior portion of the alveolar notch between P_4 and P_3 and the sliding portion was brought to the basal border of the mandible at a right angle to the aligned cheektooth row. However, the development of the ridge of bone at the anterior alveolar notch is variable and the area may be eroded in archaeological specimens. As with all our measurements we attempted to be as consistent as possible in locating this point. Distance B is the length of the toothrow. The

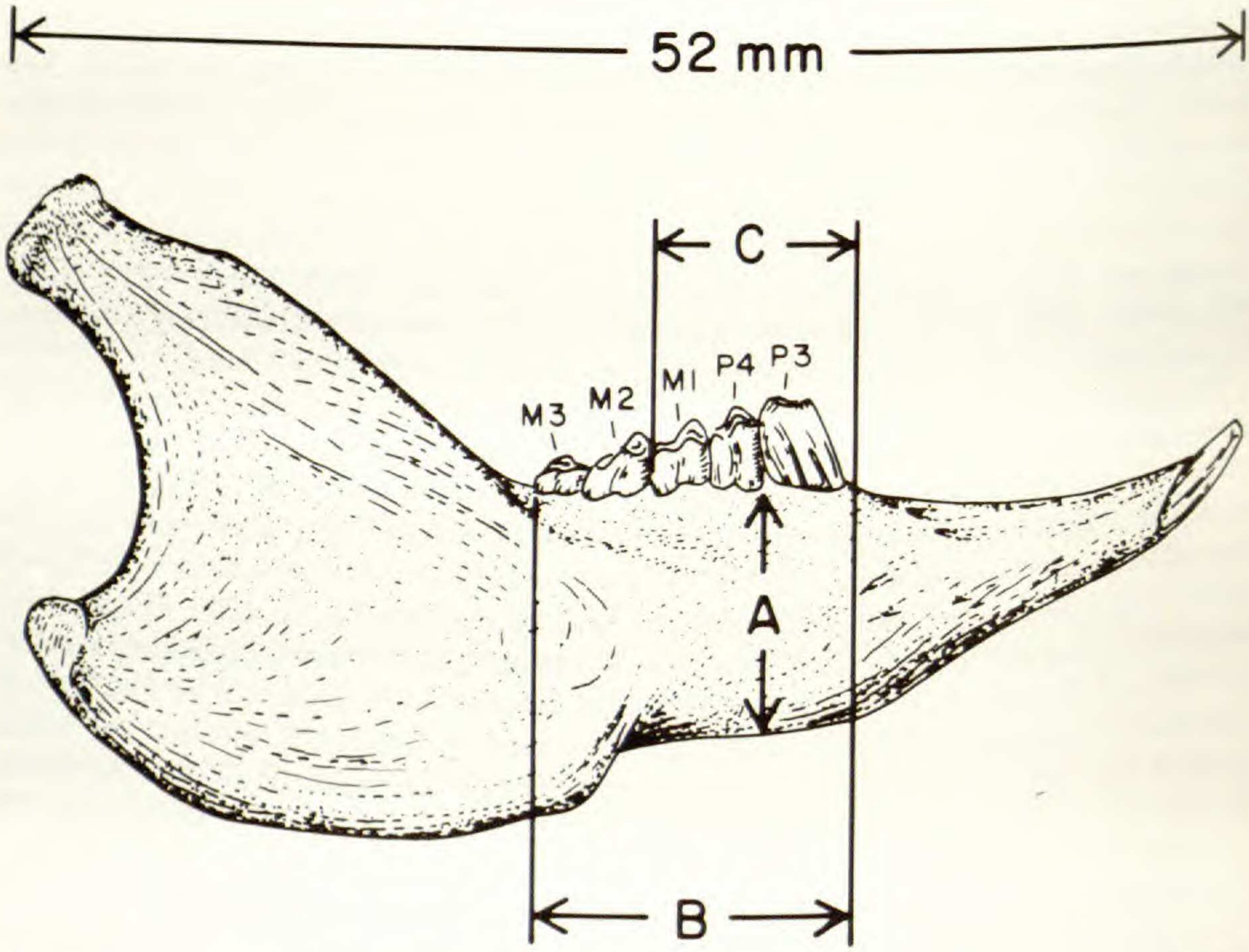

FIG. 1.—*Osteological distance on the cottontail mandible. Distance A is the depth of the mandible. Distance B is the alveolar length (P_3-M_3) and distance C is a modified alveolar length (P_3-M_1).*

measurement was taken with the calipers from the anterior alveolar notch of the third premolar to the posterior alveolar notch of the third molar. Distance C is the modified alveolar length recommended for archaeological materials. The calipers were set at the anterior alveolar notch of the third premolar and expanded to the posterior notch of the first molar in order to obtain this measurement. In our study, sample size was increased by 27 when mandibles for which only distances A and C could be measured were added.

The crenulation of the enamel border of the third premolar also was examined. Using a 10 power magnifying lens, a subjective evaluation was made on a scale of 0 to 3 with 3 assigned to very-, 2 to somewhat-, 1 to slightly crenulated, and 0 to uncrenulated specimens.

In order to classify these specimens each mandible for which distance B was present was plotted on a scattergram (Fig. 2). Mandibular depth was measured along the x-axis and alveolar length (P_3-M_4) was measured on the y-axis. An approximation of the line

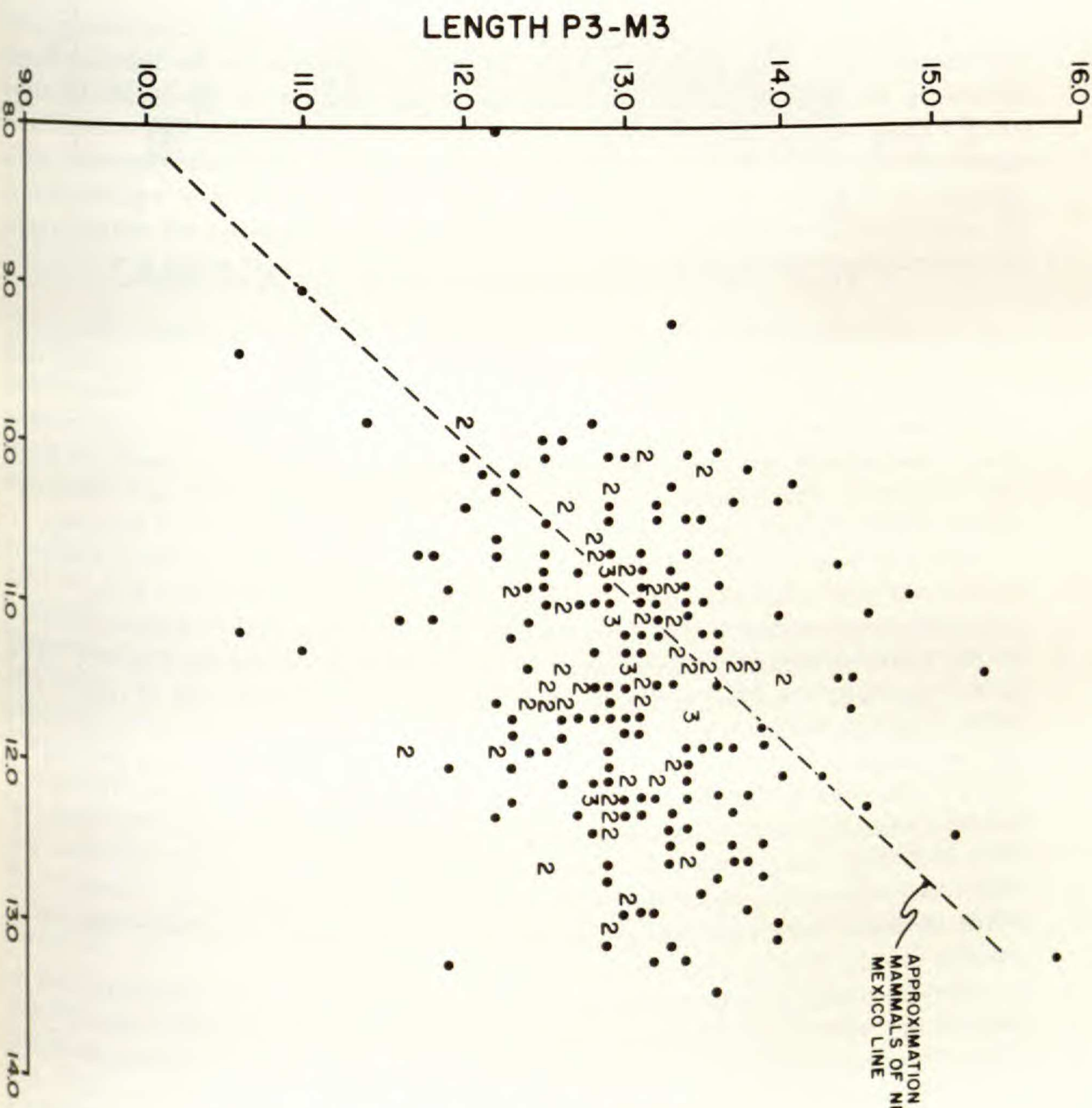

FIG. 2.—*Bivariate plot of the Dolores archaeological mandibles with the line from Findley et al. (1975:Fig. 35) superimposed. Specimens of Nuttall's cottontail are supposed to fall above the line while those of desert cottontails should fall below.*

separating desert and Nuttall's or eastern cottontail provided by Findley et al. (1975: Fig. 35) was then placed on the scattergram. Mandibles falling above the line were identified as Nuttall's cottontail while those falling below the line were identified as desert cottontail.

A second scattergram was constructed for the relationship between mandibular depth and the shorter measure of alveolar length (P_3-M_1). In this scattergram the species assignments made on the basis of the first scattergram were used to assess the probable species of the mandibles for which distance B was lacking. In those cases in which it remained unclear, the crenulation of the enamel border was used as the arbiter of probable species. However, we considered these identifications to be unreliable compared to those made obvious by the bivariate plot.

We then used the species determinations to test the expectation of localized procurement of cottontails among the Dolores Anasazi by examining distribution of species across space and through time at Dolores archaeological sites. This has been reported in Flint and Neusius (in press).

However, we remained dissatisfied with the method of species determination used. The bivariate plots established that both species were present in the Dolores area and utilized by the Anasazi. They did not indicate how reliable the species identifications were. In instances in which our subjective evaluation of crenulation of the enamel border was the primary indicator, we considered the identifications unreliable, but more subtle variation in accuracy was not obvious. Because correct identification was important to the analysis of the temporal and spatial distributions of these species, we wanted to assess our accuracy more thoroughly.

SPECIES DETERMINATIONS USING DISCRIMINANT ANALYSIS

Thus, we made a second attempt to determine species using mandibular measurements. We decided to use discriminant analysis on a group of modern cottontails whose species were known and then employ the discriminant function to classify our prehistoric unknowns. Discriminant analysis is an appropriate technique for such classification (Klecka 1980:7-8), and provides probabilities for the group assignment of each case.

The U.S. Fish and Wildlife Service in Fort Collins, Colorado provided a sample of known cottontail mandibles from their skeletal collections. Distances A and B for 41 adult individuals already had been measured, and we were able to measure distance C on the same individuals. Twenty-five of the individuals from the Fish and Wildlife Service had been identified as *Sylvilagus audubonii baileyi* at the time of capture while sixteen had been identified as *Sylvilagus nuttallii grangeri.* We also had measurements on five additional individuals from the collections at Mesa Verde National Park and Fort Lewis College which had been identified from soft tissue characteristics. One of these had been identified as *Sylvilagus audubonii warreni (Sylvilagus audubonii cedrophilus* per Hall, 1981:Map 225). One was considered *Sylvilagus nuttallii pinetis* and three were simply assigned to *Sylvilagus audubonii.* This gave us forty-six known individuals with which to work. Although this sample was not overly large, it was larger than that apparently used by Findley et al. (N=35).

Two discriminate function analyses were performed on these individuals using the program provided by the Statistical Package for the Social Sciences (Nie et al. 1975:434-467). The first of these performed a stepwise selection of three variables corresponding to the measurements for distances A, B and C. Because distance C was highly correlated with distance B, this analysis deleted distance C from consideration. Ninety-one and three tenths percent of the modern individuals were correctly classified using this function. Because those prehistoric mandibular fragments for which only distance C was measured could not be identified using this function, a second discriminant analysis was performed using only the measurements for distances A and C. Ninety-three and five tenths percent of the knowns were correctly classified using this function.[4]

Scores on the second discriminant function were then used to assign species to the 283 adult Dolores mandibles originally classified using bivariate plots. Figure 3 is a histogram displaying the distribution of cases with respect to this second discriminant function. This procedure provided us with probabilities for group membership.

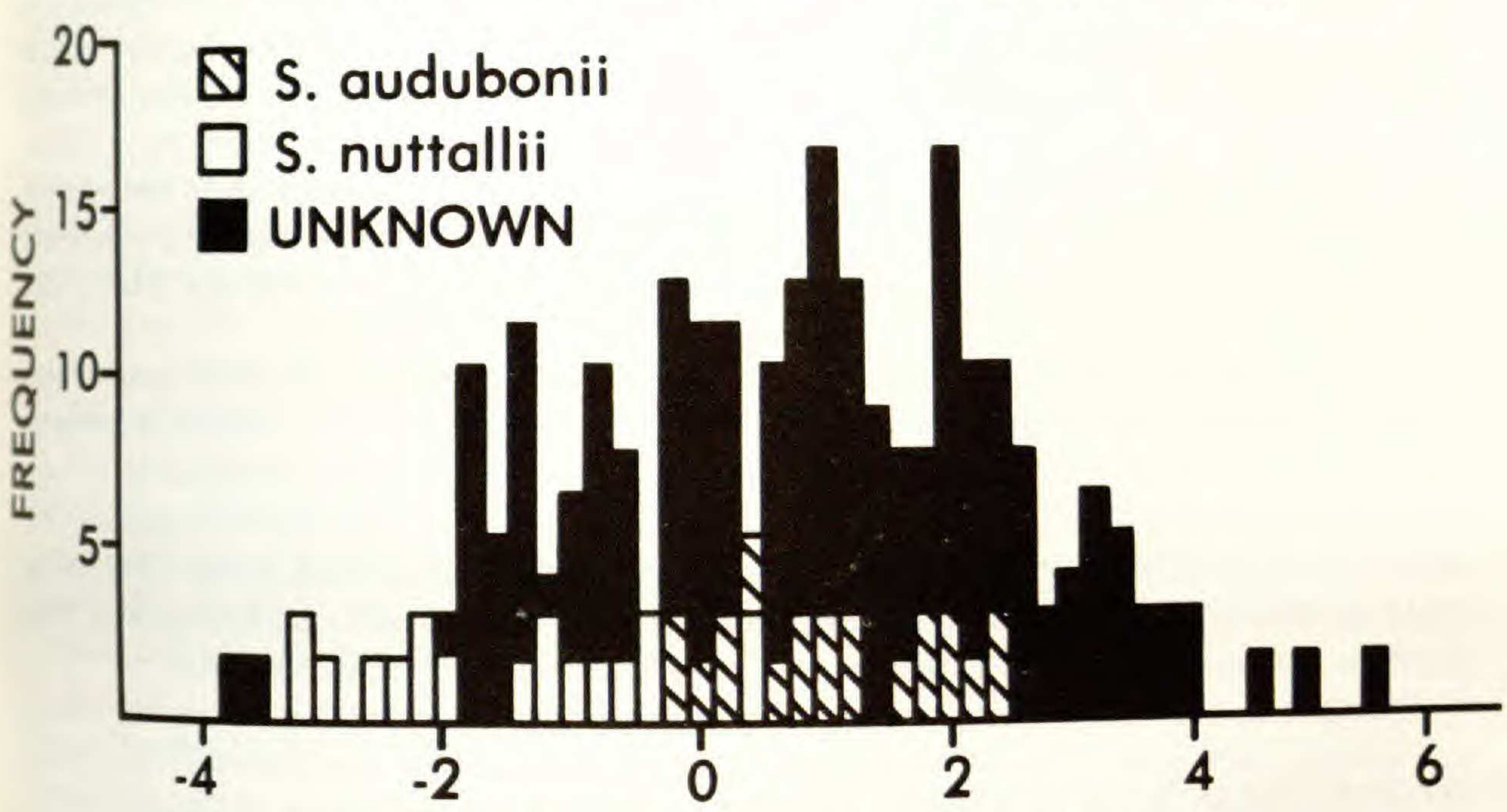

FIG. 3.–*Distribution of known and unknown mandibles along the discriminant function. Cases falling to the left of 0 were assigned to Nuttall's cottontail while those to the right were assigned to desert cottontail. Probabilities for these assignments vary according to the discriminant scores.*

DISCUSSION

The results of our work are important to zooarchaeologists. First, our analysis confirms that desert cottontails tend to have a deeper and longer mandible than Nuttall's cottontails as suggested by Findley et al. (1975), but also indicates that classification based only on this relationship is less than ideal. If we consider a probability of group membership of .90 adequate for identification, 35.8% of the prehistoric mandibles could not be identified. If a more stringent requirement of .95 is employed 45.7% cannot be identified.

Furthermore, the probabilities for those mandibles assigned to Nuttall's cottontail tend to be lower than those for mandibles assigned to desert cottontail. Over half (54.8%) of the mandibles assigned to Nuttall's cottontail have probabilities of less than .90 while this is true for only 37.6% of those assigned to desert cottontail. This may result from a smaller number of known Nuttall's cottontails or it may indicate greater variability within this species.

It is interesting that desert cottontails apparently represent such a high proportion of the prehistoric mandibles. We expected Nuttall's cottontail to predominate in the Dolores faunal assemblages both because much of the project area was forested prehistorically (Bye, in press; Petersen, in press) and because much of it was above the 7000 feet elevational limit for desert cottontail (Armstrong 1972:85). However, since our subjective observations within the project area today did not fit with this expectation, we made no attempt to weight the discriminant analysis in favor of one or the other species. Until better discrimination between these species is possible, we can only speculate that the Dolores data is important to understanding the biogeographic relationships of these species.

The discriminant analysis also results in some mandibles being assigned to a different species than was suggested by the use of bivariate plots. Thirty-nine (10.2%) of the prehistoric mandibles were assigned to a different species by the discriminant analysis. The probabilities of group membership do tend to be low for this group. Within it 74.4% of the cases are assigned to a species with probabilities of less than .90. Nevertheless, it is clear that the modern population we obtained differs from that used by Findley and his coworkers with respect to these two characters. Sample size could be a factor here, but it is also possible that subspecific variation is involved. Most of the modern desert cottontails measured by us were assigned to *S.a. baileyi*, a subspecies which does not occur in New Mexico (Hall 1981:Map 225). Similarly most of the modern Nuttall's cottontails were assigned to *S.n. grangeri* which also does not occur in New Mexico (Hall 1981: Map 223).

Finally, the use of discriminant analysis in zooarchaeological analysis may be preferable to that of bivariate plots even if such a small number of variables is involved. This is because it provides probability assessments for the species assignment of each mandible. However, the discriminant analysis also indicates that the relationships between these species is not adequately defined by these characters alone. Separation could be improved by obtaining a larger sample of known specimens, adding more characters to the analysis[5] and investigating the possibility of subspecific variation.

We intend this article as a caution to zooarchaeologists attempting to identify cottontail species. Certainly it is naive to apply the plot provided by Findley et al. to a variety of archaeological situations without further research on the variability in these characters between species. However, we do not mean to suggest that the separation of cottontails not be attempted by zooarchaeologists. A number of important behavioral and environmental questions may be addressed through detailed study of cottontail remains. We think that this is an instance in which further investigation of taxonomic and distributional relationships by zooarchaeologists is required in order to do justice to zooarchaeological data bases. We hope that this summary of our analyses serves as a stimulus to further study of this topic.

ACKNOWLEDGMENTS

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LITERATURE CITED

AKINS, NANCY J. 1984. Prehistoric faunal utilization in Chaco Canyon: Basketmaker III through Pueblo III. Unpubl. Ms. in files of authors.

ANDERSON, ELAINE. 1980. Fauna. Pp. 123-149 *in* The Durango South sites in the Durango district (John C. Gooding, ed.). Anthrop. Pap. Univ. Arizona 34, Tucson.

ARMSTRONG, DAVID M. 1972. Dis-

LITERATURE CITED (continued)

tribution of mammals in Colorado. Mon. Mus. of Nat. Hist. Univ. Kansas 3, Lawrence.

BERTRAM, JACK B and NEALE DRAPER. 1983. The bones from the Bis a'ani Community: a sociotechnic archaeofaunal analysis. Pp. 1015-1016 *in* Bis a'ani: a late Bonito Phase community on Escavada Wash, northwestern New Mexico (Cory D. Breternitz, David E. Doyel, and M.P. Marshall, eds.). Navajo Nation Pap. in Anthropology 14, Gallup.

BINFORD, MARTHA R., WILLIAM DOLEMAN, NEALE DRAPER and KLARA B. KELLEY. 1982. Anasazi and Navajo archaeofauna. Pp. 448-1057 *in* Anasazi & Navajo land use in the McKinley Mine area near Gallup, New Mexico (Christina G. Allen & Ben A. Nelson eds.). Office Contract Arch., Univ. New Mexico, Albuquerque.

BISSELL, STEVEN J. and MARY BETH DILLON. 1982. Colorado mammal distribution latilong study. Colorado Div. of Wildlife, Denver.

BYE, ROBERT A. JR. in press. Reconnaissance of the vegetation of the Dolores Project. *In* Dolores Archaeological Program Studies in Environmental Archaeology (Kenneth L. Petersen, Vickie L. Clay, Meridith H. Matthews and Sarah W. Neusius compilers). U.S. Dept. Int., Bur. Recl., Office Eng. and Res., Denver.

CORDELL, LINDA S. 1977. Late Anasazi farming and hunting strategies: one example of a problem in congruence. Amer. Antiqu. 42(3):449-461.

FINDLEY, JAMES S., ARTHUR H. HARRIS, DON E. WILSON, CLYDE JONES. 1975. Mammals of New Mexico. Univ. New Mexico Press, Albuquerque.

FLINT, PATRICIA ROBINS and SARAH W. NEUSIUS. In press. Cottontail rabbit procurement among Dolores Anasazi. *In* Dolores Archaeological Program Supporting Studies I:Settlement & Environment. U.S. Dept. Int., Bur. Recl., Office Eng. & Res., Denver.

HALL, E. RAYMOND. 1981. The mammals of North America. 2nd edition. John Wiley & Sons, New York.

HARRIS, ARTHUR H. 1963. Vertebrate remains & past environmental reconstruction in the Navajo Reservoir District. Mus. of New Mexico, Pap. in Anthropology II, Albuquerque.

_____. 1970. Past climate of the Navajo Reservoir District. Amer. Antiq. 35(3):374-377.

HULBERT, RICHARD C., JR. 1984. Latest Pleistocene and Holocene leporid faunas from Texas: their composition, distribution and climatic implications. The Southwestern Naturalist 29(2):197-210.

NIE, NORMAN H., C. HADLAI HULL, JEAN G. JENKINS, KARIN STEINBRENNER and DALE H. BENT. 1975. Statistical package for the Social Sciences. 2nd edition. McGraw-Hill, New York.

KLECKA, WILLIAM R. 1980. Discriminant Analysis. Sage Publications, Beverly Hills, California.

NEUSIUS, SARAH W. 1985. The Dolores Archaeological Program faunal data base: resource availability and resource mix. Unpubl. Ms. on file, Dolores Arch. Prog., Dolores.

ORR, ROBERT T. 1940. The rabbits of California. California Acad. of Sci. Occas. Pap. 19. San Francisco.

PETERSEN, KENNETH L. in press. Natural vegetation of the Dolores Project area, ca. 1920. *In* Dolores Archaeological Program Studies in Environmental Archaeology (Kenneth L. Petersen, Vickie L. Clay, Meridith H. Matthews and Sarah W. Neusius compilers). U.S. Dept. of Int., Bur. Recl., Office Eng. and Res., Denver.

PIPPIN, LONNIE C. 1979. The prehistory & paleoecology of Guadalupe Ruin, Sandoval County, New Mexico. Unpubl. PhD Dissert., (Anthropology), Washington State Univ., Pullman.

NOTES

[1]Since 1978 the Dolores Archaeological Program has been under contract with the U.S. Department of Interior, Bureau of Reclamation (Contract No. 8-07-40-S0562) to mitigate the effects of the construction of the McPhee Dam and Reservoir in Montezuma County, Colorado. Faunal remains have been recovered from approximately 150 archaeological sites the majority of which belong to the Anasazi cultural tradition and date between A.D. 600 and 950.

[2]The modern range of eastern cottontail is far removed from the Dolores area (Hall 1981: Map 223). Thus, we did not anticipate the presence of this species in the area during the period of Anasazi occupation.

[3]Crenulation of the enamel of all cheek teeth has been examined by Orr (1940) for California cottontails and may be useful for Colorado cottontails as well (R. Findley pers. communication).

[4]The authors are aware that more variables are normally used in discriminant analysis. However, Klecka (1980:15) specifically indicates that we have not violated any basic assumptions of this technique. We used this technique because it allowed us to assign group membership or species with a probability, the exact problem with the bivariate plots which we sought to remedy.

[5]Hulbert (1972) uses dental characters which might be of use.